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PRINCIPLES OF CHEMICOMECHANICAL AND ELECTROLYTIC METALWORKING

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Chemicomechanical Metalworking

The essence of chemicomechanical metalworking is the combination of a chemical breakdown of a very thin surface layer of metal with its mechanical removal by means of a tool.

Academician I. V. Grebenshchikov established that the process of polishing metals with the use of paste is a simultaneous mechanical and chemical process. During the process of polishing, the film of metallic oxide, under the action of the tool (polishing wheel) is removed from the surface being worked; by action of the chemical medium a new film is formed, which is again removed. With respect to the polishing process, Grebenshchikov has established the following:

1. In order that the polished surface have maximum smoothness and the fewest possible physical flaws, it is necessary that only the film of metallic oxide be removed during polishing.

2. In order that the polishing process be carried out as stated, the polishing compounds must not cut the metal, but contribute to the forming of the film and facilitate its removal. Pastes supplied by the GOI (State Optical Institute), which include in their composition surface active substances (sulfur, stearin and other materials), contribute to the forming of the films and make removal of them easier.

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3. Hard metals can be polished with materials softer than themselves (French chalk, stearin, oleic acid, red iron ocher, ammonium hydroxide, and others).

Chemicomechanical working of metals by means of polishing with surface compounds has been advanced by the use of electrolytes.

In these processes, the chemically active medium, in which the working of metals takes place, forms solid reaction products by interaction with the metal. These reaction products cover the surface being worked with a thin layer and protect it from further chemical decomposition. The protective layer is then removed with a tool and the process is repeated on the exposed metal surface under the action of the electrolyte. Thus chemicomechanical working consists of the repetition of the processes of forming a proctective layer and its removal. Inasmuch as in this process the role of the tool is not the cutting of metal but the removal of reaction products from the surface being worked, the hardness of the tool is of little importance. The process can be carried out with tools, the hardness of which is less than that of the metals being worked. For example, the hard alloy "pobedit" is ground by comparatively soft abrasives, such as emery and quartz sand. The chemically active agent in the process can be either a liquid or solid electrolyte or a gas atmosphere around the metal being worked. Nearly all polishing compounds are metal oxides; for this reason it can be assumed that the capacity of the metal to dissolve in its own oxide plays an important part in the process of polishing.

The speed of mechanical working of metals in the electrolyte depends primarily on the effect exerted by the action of galvanic microcouples or by some other electrolytic action on the mechanical integrity and stability of the protective layers, the duration of the electrolytic action on the metal, and the temperatures used or encountered in the process

The effect of various electrolytes on the efficiency of the grinding process is shown in the following table:

Amount of Metal Removed During Grinding of Soft Carbon Steel, Aluminum, and Cast Iron for 30 Minutes in Various Electrolytes

	Amount of Metal Removed (mg)		
Electrolyte	Steel	Aluminum	Cast Iron
Water	16	21.6	38
Na_2CO_3	17	18.1	26
HCI	20	22.3	42
$FeSO_4$	19	--	29
$Fe_2(SO_4)_3$	51	--	51
$K_3Fe(CN)_6$	48	--	56
$(NH_4)_2S_2O_8$	76	--	99
$CuSO_4$	299	20.2	250
$HgNO_3$*	15	--	233
NaOH	--	56.0	--

*$HgNO_3$ solution acidified with nitric acid

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The data given above show that the speed of the grinding process in most instances increases in those electrolytes in which the metals corrode most actively. When the layer being built up is characterized by considerable mechanical stability and has a stable bond with the material being ground, the speed of grinding is decreased. Aluminum is a highly electro-negative metal; it is easily passivated and covered with a layer of dehydrated Al_2O_3, which possesses unusual resistant qualities. For this reason the speeds of grinding aluminum in water and in $CuSO_4$ solutions are identical. In the medium (NaOH) which dissolves aluminum oxide, the speed of grinding is considerably increased.

There are similar data with respect to other easily passivated metals. The speed of grinding nickel and stainless high-chrome steel changes only slightly from one electrolyte to another. Only in a solution of some strong oxidizing agents, as for example $K_3Fe(CN)_6$, does there appear any increase in the speed of grinding being considerably decreased after the introduction of chamically active compounds into the abrasive suspension.

In chemical methods of working, the degree of metal removal changes in time in the following way: the thickness of the layer of metal being removed in the beginning of the processes increases proportionate to the duration of the process; after a certain interval of time, the speed of the process falls, and finally ceases because of the building up of the products of reaction on the surface of the metal inhibiting further penetration of the electrolytes to the metallic surface. In chemicomechanical methods the products of reaction are continuously removed from the surface being worked, so that the efficiency of the process is several times higher than that of purely chemical methods. By increasing the temperature of the electrolyte the speed of reaction increases. By heating the electrolyte to 65 degrees centigrade a rate which is 2.5 times as fast is achieved.

Machine Tools for Chemicomechanical Processes

Ordinary metalworking machine tools may be used for chemicomechanical processing. However, parts of machine tools coming in contact with the solution must be made of chemically resistant materials (acid-resisting steel, brass, textolite, and others).

In a number of cases, special machine tools are used. The KhMZ-1 machine tool, for example, is intended for chemicomechanical grinding of hard alloys. The electric motor drive has a power of 0.8 kilowatts at 900-1,000 revolutions per minute. The grinding wheel for sharpening cutters is of acid-resistant steel, 25KhNVA, and that for finishing, of cast iron. The lower part of the tank is enclosed in a heating jacket, at the bottom of which a coil of nichrome or some other high-resistance alloy wire is inserted, insulated from the shell by asbestos. The ends of the coil are led out and connected with a 65-volt outlet. The diameter of the nichrome wire of the coil is 1.2 millimeters; length, 24 meters.

The tank is made from cuprite or brass. Three cuprite blades are mounted on a ring in the annular space of the tank for stirring the abrasive suspension during grinding. /Sketch of KhMZ-1 unit is appended./

Grinding Hard Alloys in Electrolytic Solutions

The surface of a hard alloy in electrolytic solutions is particularly heterogeneous with respect to its electrochemical properties. The tungsten-carbide grains are the electropositive and the cobalt particles the electronegative centers of the surface. The activity of the galvanic microcells must lead to a corrosive breakdown of the cobalt bond and to exposure of the tungsten carbide grains. In grinding, however, this process should not go so far that the tungsten carbide grains are completely loosened by the corrosive action.

The corrosion process during grinding breaks down the stability of the surface layer of the alloy to a considerable extent, thus increasing the speed of the grinding.

The most effective accelerants for this process are solutions of electropositive metallic salts -- silver, copper, and mercury. In contact with these electrolytes, the metallic cobalt present in the hard alloy dissolves, displacing the electropositive metal from the solution. During grinding the volume of the electropositive metallic salt in the electrolyte steadily decreases while the content of cobalt salt increases; in order to maintain the constant concentration of the original electrolytic solution and hence the grinding speed, it is necessary to replace the spent electrolyte regularly.

The effectiveness of various accelerants is given in the table below, which shows the speed of grinding "pobedit" alloy in various electrolytes, using emery powder on a copper grinding wheel revolving 74 rpm at a surface pressure of 240 grams per square centimeter for 30 minutes.

Effectiveness of Various Accelerants

(From data of the State Optical Institute)

Electrolyte (accelerant)	Quantity of Metal Removed (mg)
Water	40
$Fe_2(SO_4)_3$	344
$CuSO_4$	1,203
$AgNO_3$	1,174
$HgNO_3$ HNO_3	1,522
HNO_3	115

$CuSO_4$ is of particularly great practical value in grinding hard alloys. In contact with the solution, the surface of the alloy becomes covered with a thin unbroken layer of metallic copper, which is then removed by the action of the abrasive powder on the grinding wheel. Grinding hard alloys in $CuSO_4$ solution consists of repeating the successive processes of corrosive destruction of the cobalt phase and building up of the copper layer, followed by the mechanical removal of this layer.

For grinding hard alloys, an acid-resistant steel, chemically stable in copper sulfate solution, should be used as material for the grinding wheel.

The following table gives the chemical composition of two acid-resistant steels suitable for grinding wheels to be used in copper sulfate solution (content in percent):

C	Mn	Si	P	S	Cr	Ni
0.40	0.20	0.70	0.35	0.30	24.0	12.0
0.55	0.50	1.50	--	--	27.0	13.5

Uniformity of grinding-wheel wear is assured by reciprocal movement of the parts being ground.

If the grinding wheel is used continuously 24 hours a day it will wear out at the rate of 1-1.5 millimeters per month.

The peripheral speed of the wheel should be 1.5 meters per second for optimum efficiency, any increase inefficiency above that speed being negligible. Thus the factor determining efficiency is the rate of the chemical reaction. The concentration of $CuSO_4$ solution recommended is 15-20 percent; the temperature should be 35-40 degrees centigrade. Size of grains in the grinding mixture, 46-60.

Chemicomechanical sharpening of tools is carried out on the KhMZ-1 machine tools with a special [illegible]x-clamp tool-holder head in which the cutters are secured. The head with the cutters fastened is placed against the grinding wheel. The process of sharpening and stopping of the machine tool is automatic. During sharpening, the head, activated by means of an eccentric, performs a reciprocating motion on the surface of the grinding wheel. The time of sharpening depends on the degree of dullness; on the average, grinding the rear edge of new cutters (initial sharpening) takes 8-12 minutes; cutters with a dullness of 0.5 millimeter, 15-20 minutes; for badly dulled cutters (1.5 millimeters), 40 minutes. After sharpening, the head is removed, the cutters are washed with water, the head again mounted on the machine, and the cutters are finished. Finishing is performed automatically on a cast-iron wheel with a mixture of kerosene, oleic acid, and boron carbide. The time for finishing cutters is low in comparison with finishing by machining. For sharpening front edges, a special attachment to the machine is necessary; this is a more difficult process than the grinding of back edges.

Chemicomechanical sharpening and grinding of hard alloys eliminate the need for difficult-to-obtain "extra"-grade carborundum wheels, makes possible automatization of the process and high productivity of the worker (who may simultaneously sharpen up to 60 cutters), and gives a smooth, even cutting edge on the cutter without the marks, graduation lines, clogging, notches, or cracking, which are unavoidable when machining. During sharpening there is no heating of the hard alloy, which completely removes any danger of the blade's cracking. There is no need for a saw during operation. A highly skilled operator is not required.

Grinding Hard Alloy Blades

For obtaining a reliable solder it is necessary to assure complete contact of the blade base with the supporting surface of the cutting-tool holder. Chemicomechanical grinding speeds the working blades, improves the finish and quality of the surface, makes it possible to detect defects on the blades such as porosity and small cracks, and does not require abrasives, which are in short supply.

The blades are secured to a brass drum with a paste of wax and rosin. The pan of the KhMZ-1 machine tool is filled with an abrasive suspension consisting of one part 5-minute abrasive (poroshok-pyatiminutn[illegible]) plus one part of a 20-percent $CuSO_4$ solution. The brass drum with blades is set on the grinding wheel as before. The time for finishing one block of blades, depending on the degree of unevenness, varies from 30 minutes to 2 hours. For grinding 30,000 blades per month one two-spindle machine tool is required.

In grinding metal-ceramic hard alloys with emery dust and $CuSO_4$ solution, a smooth, dull surface is obtained, on which any marks, graduation lines, and scratches are easily detected with a low-power microscope.

Grinding Dies

Ordinarily, hard-alloy dies are ground with "extra"-grade carborundum, boron carbide powder, or diamond dust on high-speed machine tools (1,500-2,500 rpm). Untempered bar steel is used for the needle-shaped grinding tool.

Chemicomechanical methods are particularly suited to the grinding of large dies (15-20 millimeter aperture). Grinding is done with a tapered needle-shaped grinding tool made of cuprite, bronze, or acid-resistant steel. The die is washed periodically with hot water and checked with a standard wire for correctness of diameter during grinding. The surface is then finished with a mixture of boron carbide and kerosene. A precision of 0.03-0.04 millimeter is achieved. Spindle speed for the grinding tool is 300 rpm. The electrolyte recommended is 10 grams of abrasive powder (30-minute fraction); 10 cubic centimeters of 15-percent $CuSO_4$ solution; and one gram of starch. The starch increases the viscosity of the mixture and prevents it from running off the grinding tool.

Chemicomechanical Processing of Machinery Parts

Chemicomechanical processing is particularly suited to various parts of internal-combustion engines which require precise sizing, highly finished surfaces, and close fit. Turbine, machine-tool, locomotive, general repair, and other types of plants can use such methods to advantage.

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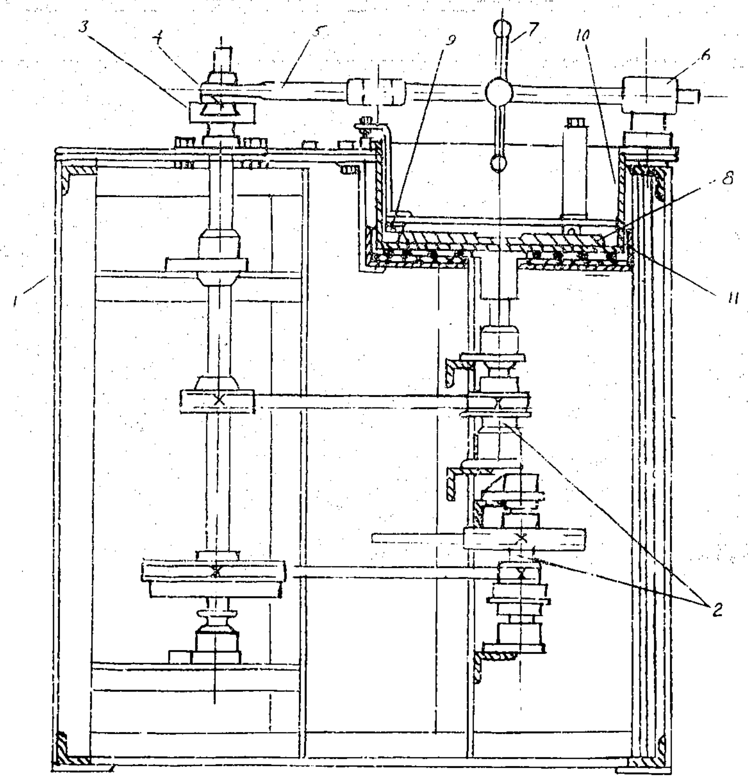
KhMZ-1 Chemicomechanical Grinder



1. Frame with table (700 x 900 x 1,000 millimeters)
2. Disk shaft and countershaft with bearings, pulleys, and belts
3. Eccentric disk
4. Cam pin with nut
5. Drive rod
6. Guide with bushing
7. Spoke
8. Grinding wheel
9. Blade
10. Tank (380 x 145 millimeters)
11. Heating jacket for tank

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